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METHOD AND INSTALLATION FOR SUPPLYING HIGHLY PURE OXYGEN BY CRYOGENIC DISTILLATION OF AIR

The present invention relates to the technique of air distillation and in particular to a method and an installation for supplying high-purity oxygen by cryogenic distillation of air.

Certain industrial applications require large quantities of impure oxygen at various pressures: gasification of coal, gasification of oil residues, direct smelting-reduction of iron ore, injection of coal into blast furnaces, metallurgy of nonferrous metals, etc.

Moreover, certain industrial plants require the simultaneous supply, in large quantities, of practically pure oxygen and impure oxygen at various pressures.

A steel production unit conventionally comprises several units having different oxygen requirements, as described in "The making, shaping and treating of steel", AISE, 1985. A blast furnace consumes oxygen-enriched air, produced in general by mixing compressed air with low-purity oxygen. The low-purity oxygen has a purity of between 80 and 97%. In contrast, converters and arc furnaces consume oxygen with a high purity of between 99 and 99.8%. To supply these two oxygen purities, two separate air distillation production units are often provided, the one producing the low-purity oxygen being a mixing-column unit of the type described in US-A-4 022 030 and EP-A-0 531 182 and the one producing high-purity oxygen being a conventional double-column unit.

All the purities mentioned are molar percentages.

When the unit supplying the high-purity oxygen is not operating, it is necessary to provide another source of high-purity oxygen, which may be another unit or at least a very large storage tank, as may be seen in "Zur Planung grosser Sauerstoffanlagen in Stahlwerken [*On the planning of a large oxygen installation in steelworks*]" by H. Springmann, Linde Berichte aus Technik und Wissenschaft, 40/1976.

The purpose of the invention is to provide an installation comprising two air separation units, the first of which, comprising a mixing column, produces low-purity oxygen and the second of which produces high-purity oxygen, it being possible for the installation to produce high-purity oxygen even when the second air separation unit is not operating, so that the high-pressure oxygen storage tank can be eliminated or reduced in size.

It is one object of the invention to provide a method for supplying high-purity oxygen by cryogenic distillation of air from an installation comprising a first air separation unit and a second air separation unit, the first air separation unit comprising a medium-pressure column, a low-pressure column thermally coupled to the medium-pressure column, and a mixing column, in which method:

i) air to be distilled is sent to the medium-pressure column;

ii) oxygen-enriched and nitrogen-enriched liquids are sent from the medium-pressure column to the low-pressure column;

iii) in a first step of the air separation unit, an oxygen-enriched liquid stream from the low-pressure column is sent to the top of the mixing column;

iv) in the first step, a low-purity oxygen stream is withdrawn from the top of the mixing column and at least one portion of this is sent to a first consuming unit;

v) in the first step, air is sent to the mixing column;

vi) in the first step, the second air separation unit supplies high-purity oxygen to a second consuming unit,

characterized in that:

vii) in a second step, in the first air separation unit, the oxygen-enriched liquid stream sent to the top of the mixing column is reduced, possibly to zero, the stream of air sent to the mixing column is reduced, possibly to zero, and the stream of low-purity oxygen withdrawn from the top of the mixing column is reduced, possibly to zero; and

viii) in the second step, a stream of high-purity oxygen is withdrawn from the bottom of the low-pressure column of the first air separation unit and sent to at least the second consuming unit.

Preferably, in the second step, the second air separation unit does not supply high-purity oxygen to the second consuming unit, or supplies part of the high-purity oxygen required by the second consuming unit.

According to other optional aspects:

- the first consuming unit is a blast furnace and the second consuming unit is a converter or an arc furnace;

- during the first step, the blast furnace is supplied with oxygen-enriched air and during the second step the blast furnace is fed either with air or with air less oxygen-enriched than that with which it is fed during the first step;

- the mixing column does not operate during the second step; and

- the second consuming unit is fed with oxygen only from the second air separation unit during the first step and is fed with oxygen only from the first air separation unit during the second step.

Another object of the invention is to provide an installation for supplying oxygen by cryogenic distillation of air, comprising a first air separation unit and a second air separation unit, the first air separation unit comprising a medium-pressure column, a low-pressure column thermally coupled to the medium-pressure column, and a mixing column, which installation comprises:

a) means for sending air to be distilled to the medium-pressure column;

b) means for sending oxygen-enriched and nitrogen-enriched liquids from the medium-pressure column to the low-pressure column;

c) means for sending a stream of oxygen-enriched liquid from the low-pressure column to the top of the mixing column;

d) means for sending air to the bottom of the mixing column;

e) means for withdrawing a stream of low-purity oxygen from the top of the mixing column and means for sending at least one portion of this to a first consuming unit;

f) means for sending high-purity oxygen from the second air separation unit to a second consuming unit, characterized in that it includes:

g) means for reducing, possibly to zero, the stream of oxygen-enriched liquid sent to the top of the mixing column;

h) means for reducing, possibly to zero, the air sent to the bottom of the mixing column; and

i) means for withdrawing a stream of high-purity oxygen from the bottom of the low-pressure column of the first air separation unit and means for sending this stream to the second consuming unit.

According to other optional aspects of the invention:

- the first consuming unit is a blast furnace and the second consuming unit is a converter or an arc furnace;

- includes means for feeding the blast furnace with low-purity oxygen from the first air separation unit and means for stopping the low-purity oxygen being sent from the first air separation unit to the blast furnace;

- the installation includes means for feeding the blast furnace with oxygen only from the second air separation unit and means for feeding the blast furnace with oxygen only from the first air separation unit;

- the installation includes at least one high-purity oxygen compressor upstream of the second consuming unit and downstream of the first air separation unit.

Exemplary embodiments of the invention will now be described in conjunction with the appended drawings, in which figure 1 shows schematically an installation according to the invention and figure 2 shows the first air separation unit in greater detail.

The air separation installation of figure 1 comprises a first cryogenic distillation air separation unit 1 and a second cryogenic distillation air separation unit 2. In a first operation of the installation, the first air separation unit produces a stream of low-purity oxygen containing between 80 and 97% oxygen. This oxygen 3 is sent downstream of the blower 4 of a first consuming unit, in this case a blast furnace 5, and is mixed with compressed air 7 before being sent to the blast furnace.

The second air separation unit 2 produces high-purity oxygen containing between 99 and 99.9% oxygen. This oxygen 8 is sent to a second consuming unit 9. The second air separation unit could be any cryogenic unit producing high-pressure gaseous oxygen, for example a

double column or a triple column, in which the oxygen is pressurized either by compressing the gaseous oxygen or by pumping liquid oxygen followed by vaporization. Examples of production methods of this kind may be found in EP-A-0 504 029.

In the second operation, the second air separation unit 2 is not operating. The first air separation unit produces high-purity oxygen 11 and, after being compressed in the compressor 13, this is sent to the second consuming unit 9. The first air separation unit either produces no low-pressure oxygen, so that the blast furnace is fed only with air, or produces less low-pressure oxygen and mixes this with air 7.

The air distillation unit shown in figure 2 is designed to produce, in a first operation, low-pressure oxygen, for example having a purity of 80 to 97% and preferably 85 to 95% at a specified pressure P substantially different from 6×10^5 Pa abs, for example 2 to 5×10^5 Pa or advantageously at a pressure above 6×10^5 Pa abs by at least 2×10^5 Pa and possibly ranging up to about 30×10^5 Pa, preferably between 8×10^5 Pa and 15×10^5 Pa. The air separation unit essentially comprises a heat exchange line 1A, a double distillation column 2A, which itself comprises a medium-pressure column 3A, a low-pressure column 4A and a main condenser-reboiler 5A, and a mixing column 6A. The columns 3A and 4A typically operate at about 6×10^5 Pa and about 1×10^5 Pa, respectively.

As explained in detail in the document US-A-4 022 030, a mixing column is a column that has the same structure as a distillation column but is used to mix, in a manner close to reversibility, a relatively volatile gas, introduced at the bottom of the mixing column with a less-volatile liquid introduced at the top of the mixing column.

Such mixing generates refrigeration and therefore reduces the power consumption associated with the distillation. In the present case, this mixing is also profitably employed for the direct production of impure oxygen at the pressure P, as will be described below.

The air to be separated by distillation, compressed to 6×10^5 Pa and suitably purified, is conveyed via a line 7A to the base of the medium-pressure column 3A. Most of this air is cooled in the exchange line 1A and introduced into the base of the medium-pressure column 3A, and the remainder, boosted at 8A and then cooled, is expanded to the low pressure in a turbine 9A coupled to the booster 8A and then injected at an intermediate point on the low-pressure column 4A. "Rich liquid" (oxygen-enriched air), withdrawn from the bottom of the column 3A, is, after being expanded in an expansion valve 10A, introduced into the column 4A, close to the point of injection of the air. "Lean liquid" (impure nitrogen) withdrawn from an intermediate point 11A on the column 3A is, after being expanded in an expansion valve 12A, introduced into the top of the column 4A, this gas, constituting the waste gas of the installation, and the pure gaseous nitrogen at the medium pressure, produced at the top of the column 3A, are warmed in the exchange line 1A and discharged from the installation. These gases are indicated in figure 1 by NI and NG respectively.

Liquid oxygen, of relatively high purity depending on the setting of the double column 2A, is withdrawn from the bottom of the column 4A, raised by a pump 13A to a pressure P1, slightly above the aforementioned pressure P, in order to take account of the pressure drops (P1-P of less than 1×10^5 Pa), and introduced into the top of the column 6A. P1 is therefore advantageously between 8×10^5 Pa and 30×10^5 Pa, preferably between 8×10^5 Pa and 16×10^5 Pa. Auxiliary air, compressed to the same pressure P1 by an auxiliary compressor 14A,

which may be the blower 4, and cooled in the exchange line 1A is introduced into the base of the mixing column 6A. Three fluid streams are withdrawn from said mixing column: from its base, liquid similar to the rich liquid and joined with the latter via a line 15A provided with an expansion valve 15A'; at an intermediate point, a mixture essentially consisting of oxygen and nitrogen, which is sent to an intermediate point on the low-pressure column 4A via a line 16A provided with an expansion valve 17A; and from its top, impure oxygen which, after being warmed in the heat exchange line, is discharged, substantially at the pressure P, from the installation via a line 18A as production gas OI.

Figure 2 also shows auxiliary heat exchangers 19A, 20A, 21A for recovering the refrigerating power available in the fluids circulating in the installation.

As will be understood, thanks to the presence of a separate circuit for the auxiliary air feeding the column 6A, the pressure P of the impure oxygen produced may be chosen at will. In addition, as indicated above, by adjusting the double column it is possible to obtain various degrees of purity for this gas.

In the second operation of the air separation unit 1, pump 13A is stopped so that the liquid oxygen is no longer withdrawn from the bottom of the column 4A and introduced into the top of the column 6. The auxiliary air is no longer introduced into the base of the mixing column 6A. The three fluid streams are no longer withdrawn from the latter.

Alternatively, in the second operation, a reduced quantity of liquid oxygen, compared to that delivered during the first operation, is withdrawn from the bottom of the column 4A, raised by the pump 13A to the pressure P1 and introduced into the top of the column

6A. A reduced quantity of auxiliary air is introduced into the base of the mixing column 6A and the three fluid streams withdrawn from the mixing column are also reduced.

Irrespective of whether the mixing column remains in operation or not, a gas stream 11 of high-purity oxygen containing between 99 and 99.8% oxygen is withdrawn from the bottom of the low-pressure column in the second operation, this stream not being withdrawn during the first operation or being withdrawn in very small amounts as a purge of the condenser 5A. This stream 11 is compressed in the compressor 13 and sent to the second consuming unit 9, which may be an oxygen converter for converting pig iron or an arc furnace. Some of the high-purity oxygen may also be delivered for oxycutting. If the stream 8 is raised up to its final pressure by another compressor, this other compressor may serve for compressing the stream 11 when the stream 8 is no longer supplied and the compressor 13 no longer required. Likewise, if the compressor for the stream 8 is not operating, for example because of a breakdown, during the first operation the stream 8 may be compressed in the compressor 13.

It is possible to extend the concept of this invention to other types of separation unit. For example, it is possible to produce impure oxygen with a first separation unit and pure oxygen with a second separation unit and to modify either the operation of the first separation unit or the first separation unit itself, so as to allow the latter to produce pure oxygen. This kind of modification would apply for example to a double-column separation unit with an auxiliary column fed at the top with impure oxygen coming from the bottom of the low-pressure column, the auxiliary column having a bottom reboiler. The auxiliary column could be fed so as to allow pure oxygen to be withdrawn from the bottom of the auxiliary

column only during one particular operation of the separation unit.

It is obviously possible to exploit the invention with a mixing-column separation unit different from that shown in figure 2.

By supplying the streams 8 and 11 at the same time, it is possible to maximize the production of high-purity oxygen, preferably by stopping the operation of the mixing column.